Optimizing Amateur Radio Resources for Major Disasters

How a single radio operator can provide emergency HF e-mail service to three hospital EOCs at once.

Victor Cid, W3CID, and Andrew Mitz, WA3LTJ

Hams have a long history of technical development for disaster preparedness. The National Library of Medicine (NLM), part of the National Institutes of Health (NIH), has tapped a technically savvy group of hams in the Washington, DC area to develop last resort e-mail communications for three area hospitals. This ambitious project has created a new approach to providing e-mail service to large groups of users during major disasters.

BHEPP — a Unique Partnership

The project began in Bethesda, Maryland where you will find three very different major hospitals across the street from one another. The Bethesda Hospitals' Emergency Preparedness Partnership (BHEPP) was created in 2004 by the National Naval Medical Center (NNMC), the "flagship" hospital of the Navy, the National Institutes of Health Clinical Center (NIHCC), a world-famous research hospital, and the Suburban-Johns Hopkins Hospital, an acute care hospital with a regional trauma center. BHEPP is the first military-civilian-federal partnership in the US.[1] The Partnership received funding to conduct a series of research, development and infrastructure projects. The NLM, the world's largest medical library and a leading medical-informatics research facility, joined the partnership in 2008 and leads the implementation of the projects. After recruiting a team of ham and MARS radio experts, the project leaders set out to develop the BHEPP MARS/Winlink2000 Emergency Radio e-mail System (BMERS).

Could It Be Done?

Could a single ham (or MARS) radio operator with a single Winlink 2000 station provide emergency e-mail service to not just a fully staffed emergency operations center (EOC), but to three large EOCs at once? After many months of research and development, these hams found the answer and have a prototype system to prove it.

EmComm and HICS

As ARRL Emergency Preparedness Manager Mike Corey, W5MPC, will tell you, if you are going to provide emergency communications (EmComm) for an agency, you had better understand how that agency operates. Health facilities such as the BHEPP hospitals use the Hospital Incident Command System (HICS) to manage emergencies.[2] This system provides an organizational and operational model that the hospitals train for and activate in case of an emergency. If the HICS is activated during an emergency, each

[1]Notes appear on page 34.

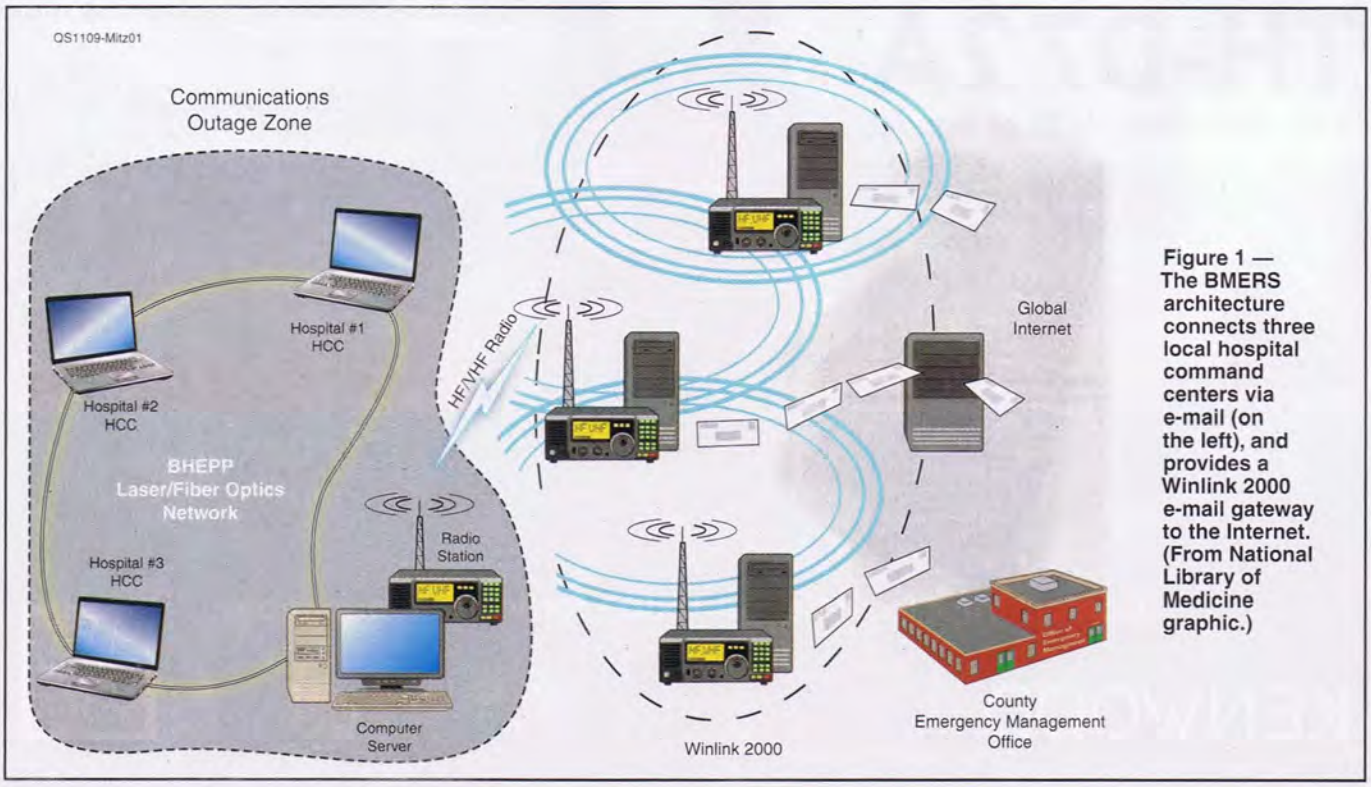

Figure 1 — The BMERS architecture connects three local hospital command centers via e-mail (on the left), and provides a Winlink 2000 e-mail gateway to the Internet. (From National Library of Medicine graphic.)

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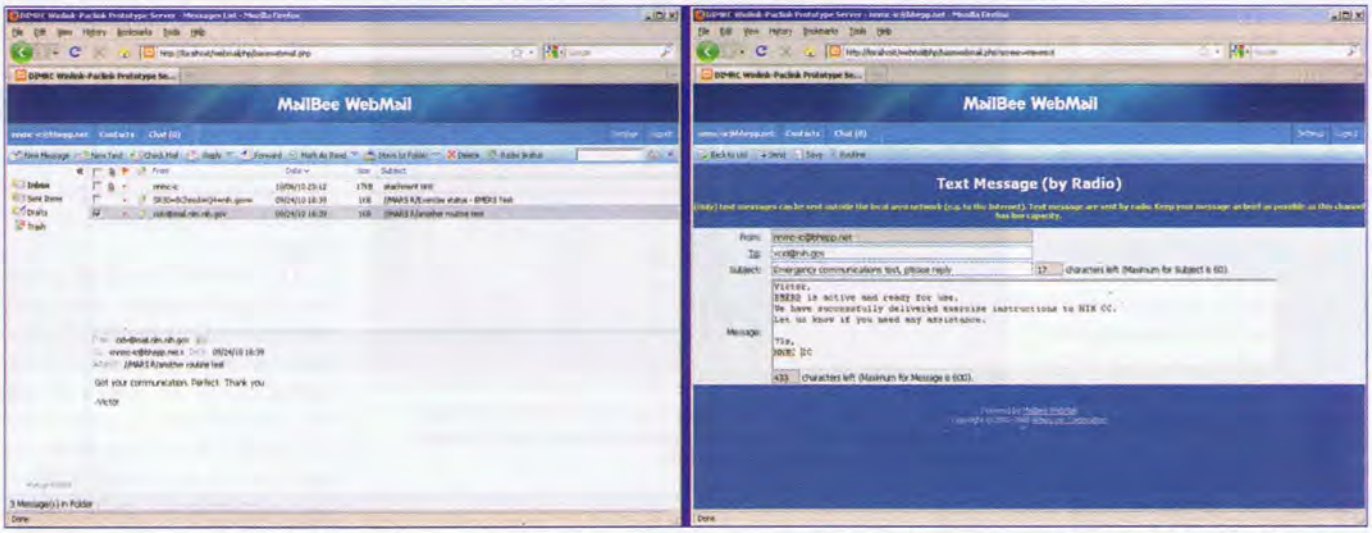

Figure 2 — The e-mail interface with a traditional web mail mailbox on the left and the "text message" interface on the right. Most users are allowed WL2K Internet e-mail access only through the text message interface.

hospital implements a Hospital Command Center (HCC, the hospital equivalent to an EOC), in which people trained on HICS perform specific roles and functions to manage the emergency.

The BHEPP hospitals have an emergency plan that uses HICS for sharing resources and information, and managing patient surge. For example, stable patients occupying beds at Suburban Hospital can be transferred to the NIHCC to make room at Suburban for new trauma patients. Communications among the three hospitals and with county, state and federal agencies is critical. The BHEPP Communications/Information Management Plan only works if they can communicate during an emergency.

At the beginning of the project the hospital emergency directors emphasized accurate and timely information exchange between the hospitals. There are multiple BHEPP projects and several pertain to the electronic capture and exchange of patient, logistic and other data. The hospitals made it clear at the project's inception that our job would be to provide e-mail if a widespread disaster destroyed or saturated Internet access. They envisioned an event as widespread and disruptive as Hurricane Katrina.[3]

The Team

When BHEPP asked the NLM to propose a last-resort emergency communications system, it was clear from the start that the solution had to include radio amateurs. The NLM approached the NIH Radio Amateur Club (NIHRAC), and through them the larger Amateur Radio community. By the end of this project we had professional and volunteer resources from the US Navy, NIH, a large local radio club (Montgomery Amateur Radio Club, MARC) and the Army branch of the Military Auxiliary Radio Service (Army MARS). Along the way, two team members got their first ham radio licenses just before or during the project, several members got their first MARS licenses, and both radio clubs hosted BHEPP and Army MARS presentations. The cross-fertilization of EmComm resources was a major success, but what about the project? Could we find a technical solution to servicing the e-mail needs of three major hospitals at once?

The authors lead the team in their pursuit of this goal. Victor Cid is in the Disaster Information Management Research Center at NLM. Andrew Mitz is an NIH engineer/scientist and president of the NIH Radio Club. James Sears, WA3MEJ/AAT3OK, the Army MARS Maryland State Director at the time, served as the MARS liaison and provided endless hands-on experience. Captain Mary Chaffee, K1MWC, was the NNMC project manager, a health professional and a well-published emergency management expert who kept the project on track. Shawn Moozoun was an administrative support contractor whose interest in every technical detail helped nail down the core architecture of the project.

Selecting a Platform

The team received substantial funding for a 1 year research effort. In the first months the team explored a number of emergency communications options that included satellite and other commercial alternatives. Winlink 2000 (WL2K) was the technology of choice.[4,5] We determined that WL2K over HF offered the best method to supply e-mail to the BHEPP EOCs if other services have failed. Even though WL2K relies on a volunteer based infrastructure, it has demonstrated its effectiveness time and again during real disasters.[6] E-mail would not only enable the hospitals to optimize the available radio resources, but also exchange information efficiently and accurately. Implementation and recurring costs of the solution were also important decision factors; we had to develop an effective solution that was affordable both to install and to maintain. We also wanted a solution that other organizations could reproduce for their own use.

Army MARS Involvement

There was no question that we needed Army MARS support for key resources, such as access to MARS-only WL2K RMS stations and the engineering knowhow to design and build resilient radio stations. Seasoned Army MARS operators always bring practical communications experience based on real life emergency support. The MARS Radio Service frequencies can be used for tests and drills much more freely than the Amateur Radio Service bands. As this project was being developed, the use of amateur frequencies during exercises for the government by their employees was mostly excluded under FCC Part 97.113 regulations. During the first year, Army MARS and NIH established a Served Agency Agreement and several MARS call signs were assigned to NIH.

This Is Harder Than We Thought!

We started with a great deal of enthusiasm and, admittedly, some bravado. Reality, however, quickly intervened. WL2K was designed to be used primarily by one remote user for Internet e-mail access via an HF or VHF radio link. *Paclink*, the main client software tool for accessing WL2K, allows the sharing of a single transceiver link among a few users across a Local Area Network. However, the WL2K model assumes that the users are licensed operators sending and receiving a relatively small number of electronic messages, all of them transmitted through the radio link. This

model works well in many places, such as a Red Cross shelter. But linking hospital HCCs/EOCs together is a different matter. The hospital workers must exchange a great volume of e-mail traffic among themselves. Only a select few e-mails should get transferred over the radio network. The shared use of the radio link must be carefully managed as a scarce resource. We realized that adapting the WL2K model to the needs of the multi-hospital community was going to be the central challenge of our project.

Figure 3 — Andy, WA3LTJ, helps test the BMERS portable station during a drill. The power generator and wi-fi bridge (on a tripod) are visible on the left.

The BHEPP hospitals did have one very special resource. As a result of another R&D project conducted by NLM, BHEPP had created a private fiber optic network (called BHEPPnet) linking the hospitals' HCCs together. BHEPPnet was designed to remain in operation even if the Internet and other networks were not available. With this local hardwired network in place, we set out to find some way to build a BHEPPnet e-mail server and seamlessly link it to a Winlink 2000 Internet gateway.

The Solution — BMERS

After about a year of development, the team came up with two solutions, one portable and one infrastructure based. The infrastructure based solution allows HCC staff to access the e-mail service via any computer connected to the private laser network. The portable solution provides a deployable radio station with emergency power that can supply e-mail services on demand to a single HCC or to an emergency response team in the field. Either station can be managed by a single MARS or Amateur Radio operator at a location optimized for the operating location (for example, near a good antenna site).

At the core of BMERS is a specially configured Internet (web) e-mail server (Figure 1). On a moment's notice, the BMERS e-mail system can be booted up, providing user accounts and web e-mail access to any laptop or other computer plugged into the BHEPPnet optical network. All the e-mail accounts in the server are pre-configured based on hospital-specific HICS roles.

Users can exchange unlimited e-mails (with or without attachments) with each other and among the hospitals via web mail by taking advantage of the high-speed laser network access to the web e-mail server. E-mails addressed outside of the BHEPPnet are rejected. However, each user account has a special button on the web mail page for sending a message over the Internet. This link provides access to the WL2K service, as described below.

All e-mail traffic sent by radio goes through a single "winlink.org" e-mail account, which acts as a gateway between the BHEPP users and WL2K. This architectural approach required extensive web server configuration, but it enables the system to handle an unlimited number of local user accounts. The user's e-mail address is automatically embedded in the body of the outgoing messages. Instructions are added to the message telling the recipient how to reply. When people who received these BHEPPnet messages through the Internet reply properly, the return message is received through WL2K and automatically ends up in the original user's mailbox. This automatic delivery of e-mails between individual BMERS users and Internet users removes the radio operator from the mail delivery loop.

Automatic routing is the key to needing only one operator to service three HCCs/EOCs. Before the development of this routing system, emergency communications among local users was handled separately from e-mail sent through the Internet. This separation was critical, since all e-mail on the WL2K system goes out over the air. With manual routing, the operator of the WL2K radio station has to be on site to interact with the users. Messages were copied from one e-mail system to the other, often using *Windows* "cut-and-paste." Incoming and outgoing messages were tracked manually, with the operator responsible for all bookkeeping. The operator was responsible for making sure that messages received from Winlink were properly routed to their intended local customers.

With the operator taking such a direct role in message handling, the operator needed to keep track of who is performing what role in the HCC/EOC. The operator had to track all changes of staff in the HCC/EOC to locate the proper recipient of incoming messages.

BMERS provides an integrated communications service, for both local and remote communications, that requires little operator intervention. The operator's main role is to ensure that the radio connections with the WL2K system are established when needed. Message routing is automatic. No message transcription is necessary. "Hot wash" (post exercise review) is greatly simplified due to the automatic message logging capabilities of the system. The message addressing is all role based, meaning that the operator does not need to track EOC personnel or staff changes.

The address book of every user account includes the e-mail addresses of all the HCC roles from the three hospitals that are making use of the system. By not requiring the radio operator at the HCC/EOC, the radio system can be moved to an optimal location. Our infrastructural radio station is at the NIH Radio Club station, separate from the three HCCs and right underneath our antenna farm.

Bandwidth Catastrophe Prevention

Removing the radio operator from the routing loop has a cost. Users must somehow be forced to limit the size and distribution of Internet messages to avoid unnecessary radio traffic. BMERS was developed for major regional Internet outages, so the main focus has been on HF operations. VHF and UHF operations can move messages at a higher data rate, but the concept of bandwidth catastrophe discussed here is still the same. The bandwidth offered by a HF radio link is extremely limited, even when using the fastest amateur HF protocol available, PACTOR III.

Even under excellent propagation conditions, it is difficult to transfer more than a few hundred characters per second or the equivalent of around 14 pages of single spaced text each minute. Under more realistic conditions, the throughput is a few pages of text per minute, not counting the time it takes to establish a connection between the emergency radio station and a remote WL2K RMS server station. Large graphics sent in one e-mail can tie up the HF channel for minutes at a time. It is easy to see that some sort of bandwidth management is essential. If the operator is handling each and every message, he/she can manually regulate the amount and type of traffic that gets sent out. On an automatic system, a different mechanism for bandwidth discipline is needed.

Before we explain the techniques used by BMERS, consider that one poorly composed e-mail can bring the entire system to its knees with no simple mechanism for recovery. For example, if a user sends a single message to a dozen Internet recipients and asks them to acknowledge the message's arrival, a dozen replies that copy the original message will produce 12 times the original radio traffic. Once the message leaves the local network, there is no way to stop the multiple replies

from queuing on the Internet side of the radio link. The incoming flood of traffic can potentially choke the radio system for many hours, especially if some e-mail replies include fancy multimedia components now common on the modern Internet. There is nothing the radio operator can do to clear the incoming e-mail queue, except wait for all the e-mails to be downloaded.

We needed to implement automatic bandwidth usage control mechanisms in the software. BMERS restricts the message format and addressing format of Internet e-mails. Internet e-mails from local users are not allowed to include multiple destination addresses. The internal e-mail interface looks like common web mail services, such as Hotmail or Gmail, but the user can access Internet e-mail only via a special button on the web mail page. The Internet e-mail composing interface is cleverly designed to resemble a text messaging or Twitter interface. It allows users to send text-only messages of limited length (currently 650 characters), no attachments, and it displays a character counter that is decreased as text is entered.

Only a single Internet recipient is allowed. Also, the messages are automatically stripped of unnecessary characters and a note is added to the message explaining the recipient how to reply properly. Large e-mails or long Internet recipient lists are impossible through this interface. This approach practically eliminates accidental e-mails from local users across the HF radio link. Should it become necessary to send a large or widely distributed e-mail, there is one user account on the system that provides unrestricted Internet e-mail access. Only specially trained personnel are permitted access to this account.

If, for any reason, an overload of incoming traffic does occur, there is one extraordinary measure that can be used to recover. The system can be rapidly reconfigured to use an alternative Amateur Radio or MARS call sign that points to a different winlink.org account. Moving to a new account switches to an entirely new e-mail box on the central mail server (CMS). All old e-mails are abandoned and this new gateway e-mail address is used, but local accounts remain the same. The NIH Radio Club has three MARS call signs and three Amateur Radio call signs expressly for this purpose.

Software Components

The standard WL2K *Paclink* program is used to handle the packet modem and radio. An open source mail server application, *hMailServer*, handles the routing of local and Internet e-mail messages and performs a number of required checks and transformations on them. The user interface is provided by an Apache web server and an extensively customized copy of the AfterLogic *Webmail Pro* application (Figure 2). The version of *Webmail* used was donated by AfterLogic to the WL2K community and we modified it to accommodate the additional functionality needed. The web server can also be used by the hospital HCCs/EOCs or the radio operator to broadcast information to the local user community. The same software configuration is used for both the infrastructural and the portable solutions.

Infrastructural Solution

The laser network connects the hospitals' HCCs together forming a common local area network (called BHEPPnet). A dedicated fiber optic connection links the NIH Radio Club station to BHEPPnet. The club station has the server and radios. Users at the HCCs just point their web browsers to the mail server and login to their e-mail accounts assigned by the Incident Commander according to their designated HCC roles. The radio station has large multiband antennas for WL2K operations. Volunteer Amateur Radio and/or MARS operators, many of them club members, have access to the station for training, drills and regular radio club activities. Thus, the equipment is readily available for both training and emergency operations. Employees of NIH or the other BHEPP organizations may be restricted under Part 97.113 of FCC regulations, whereas non-employee volunteers are not.

When BMERS is in operation, users at the hospitals can communicate with the radio operator at the NIH Radio Club using e-mail. The operator can make radio and e-mail queue information available automatically to the users via the web server used by the web mail program.

Portable Solution

While developing this system we decided to build a portable, ruggedized version of BMERS (Figures 3-5). The computer server, which is also the operator's console, is a ruggedized laptop running Microsoft *Windows XP Pro*. Power can be provided by a gas generator, batteries or the power grid. We implement an Ethernet local area network (LAN) around the radio rig, providing HCC or disaster response personnel with wireless and wired connectivity to the e-mail service. A high-gain Wi-Fi bridge is also available to extend the LAN inside a building or to a far-away location.

The portable station has many potential uses. For example, if an HCC/EOC is forced to relocate after building damage, the portable station can be set up in a field or on a parking garage, and beam the network connection into the temporary HCC/EOC site.

Hamspeak

HF — High frequency, the portion of the radio spectrum extending from 3 to 30 MHz, also called *shortwave* and including the 80 through 10 meter amateur bands. HF is above MF (300 kHz to 3 MHz, and includes the 160 meter amateur band) and below VHF (30 MHz to 300 MHz, which includes the 6, 2 and 1¼ meter amateur bands).

MARS — Military Auxiliary Radio System. Organizations providing non-operational communications support, such as health and welfare traffic, to each of the US military services. MARS operators are generally also licensed Amateur Radio operators using their own equipment on special frequencies just outside the amateur bands. They have special MARS licenses and assigned call signs and operate under MARS procedures.

PACTOR — Amateur digital communications protocol that features an error correcting mechanism.

UHF (ultra high frequency) — The radio frequencies from 300 to 3000 MHz.

VHF (very high frequency) — Radio frequencies from 30 to 300 MHz. Included in this range are the 6, 2 and 1¼ meter amateur bands.

Wi-Fi bridge — Packet routing equipment used to interconnect personal computers and other systems on a local area network using a wireless link to some or all nodes. The wireless link provides short range connectivity using radio operating in the UHF region under the protocol standardized by IEEE 802.11.

Winlink 2000 — Worldwide Amateur Radio based radio messaging system that provides noncommercial Internet connectivity to remote users.

System Testing

The portable solution has been successfully tested in a number of exercises, including a demonstration during the Collaborative Multiple-Agency Exercise in October 2009 (CMAX-09).[7] At the time of this writing, the fixed station has been tested only from within the NIH Radio Club room and not from the hospital HCCs/EOCs. The installation of the network connection between the BHEPPnet laser network and the NIH Radio Club station is just now being finished.

Current and Future Activities

The BHEPP community is funding a number of enhancements to the two BMERs solutions. New software features will allow better message traffic control. Users will be able to communicate via instant messaging with each other and with the radio operator, and additional automatic system reports will be available to users and the radio operator. The operator will be able to easily and

Figure 4 — Front of the BMERS portable station. The HF rig (a Kenwood TS-480SAT) and PACTOR modem (SCS PTCII) are on the left. A UHF/VHF rig (IC-208H) and packet modem (Kantronics KP3-C+) are on the right.

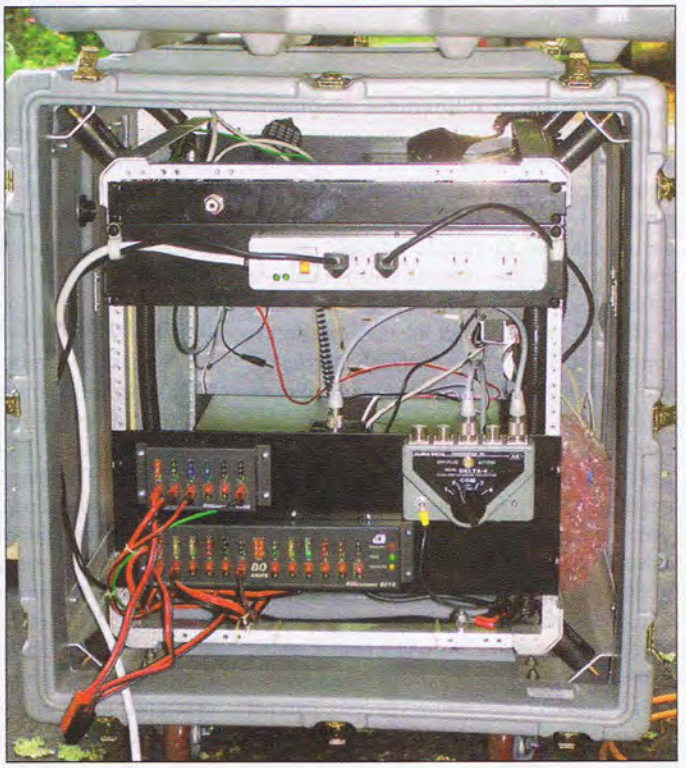

Figure 5 — Back of the BMERS portable station. Note the ruggedized, waterproof carrier. The station runs on either 120 V ac using a pair of built-in Astron 25 A switching power supplies, or 12 V dc with a 250 W inverter for ac accessories.

rapidly switch the system between ham and MARS operation, and easily configure many system parameters via a custom management user interface.

A new, more compact and flexible portable radio station will be easier to deploy. An innovative power system is being built to allow for an unprecedented flexibility in the types of power sources available to the radio station. The new power system will automatically switch from battery to generator, or even solar power, depending upon which source is available. It can also provide power to local users. The base station is being rebuilt for greater reliability and to support more users.

The BHEPP laser network is being extended to the NIH Radio Club via a private fiber optics link for maximum reliability. Training materials and activities are being planned to enable hospital personnel to use and manage the system. Future research and development could explore ways to increase the throughput of the radio system, and could make it easier to use BMERS with different computer operating systems and radio equipment.

The BHEPP community will again include the BMERS in their next annual CMAX drill, but this time the communications system will play a much larger role during the simulated disaster. We expect to publish more technical details of the system we developed, and make the software and the documentation available to the ham community in the future. Stay tuned for more.

Acknowledgments

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Notes

[1]For more information about BHEPP, see **www.bethesdahospitalsemergencypartnership.org/**.

[2]HICS is described at **www.emsa.ca.gov/hics/**.

[3]R. Lindquist, N1RL, "The Katrina Chronicles 1," *QST*, Nov 2005, p 43, and "The Katrina Chronicles 2," *QST*, Feb 2006, p 50.

[4]R. MacDonnell, VE0RDM/VK4BDM/YJ8DM, "Squeezing More from Winlink 2000," *QST*, Jun 2006, pp 28-31.

[5]For more information about Winlink 2000, visit **www.winlink.org/**.

[6]**www.winlink.org/node/12**

[7]For more information about CMAX-09, see **www.navy.mil/search/display.asp?story_id=49042**.

Photos by W3CID

ARRL member and General class licensee Victor Cid, W3CID, is a senior computer scientist with the National Library of Medicine (NLM), Office of the Disaster Information Management Research Center. NLM is part of the National Institutes of Health (NIH), the medical research agency of the Department of Health and Human Services.

He got his ham ticket in January 2008, mainly because of his work on this project, but has been a fan of ham radio since his early years, having participated on a few Jamborees on the Air at CE3BSC, the official radio station of the Boy and Girl Scouts of Chile. Victor is also an auxiliary operator with Army-MARS (AUX3AH), and a member of the NIH Radio Amateur Club (NIHRAC). He has great interest in digital modes and stealth antennas (as many other hams, he lives in a community with antenna restrictions). Victor holds degrees in computer science and telecommunications management. Victor can be reached at 6701 Democracy Blvd, Suite 1030 MSC 4876, Bethesda, MD 20892-4876 or at **vcid@nih.gov**.

ARRL member and Amateur Extra class licensee Andy Mitz, WA3LTJ, is a research scientist at the National Institutes of Health (NIH) and the president of the NIH Radio Amateur Club. At the NIH he applies electrical engineering to brain research problems. He describes his work environment as "smart people doing good things with very cool toys." Andy earned his first license in 1968 and immediately became an avid ARRL Field Day operator. He still enjoys Field Day competition as well as casual HF DXing and public service. However, it is more common to find him in his basement shop restoring old radios or trying out new technologies. Over the years, he has built lots of radios, antennas, test equipment, automated lab instruments and mechanical gizmos. Ham radio and technology have changed a lot over the years, Andy notes, and his philosophy is to embrace those changes. Andy can be reached at 4207 Ambler Dr, Kensington, MD 20895-4002 or at **arm@nih.gov**.